

SDC SOLENOID DESIGN NOTE #196

TITLE: Stress Analysis for Prototype Vacuum Shell Supported by Two Cradles
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DATE: Feb. 10th, 1993

This design note contains a stress analysis for a prototype vacuum shell supported by a cradles at each end of shell as shown in Fig. 1. The cradle is made of aluminum with a 12" thickness and an opening angle 120 degree (1). Total load is assumed to be about 8.7 ton including the weight of the inner shell, outer shell, bulkhead, fixture and internal cold mass. Only 1/4 structure is used in the modeling because of symmetry. The gap element is used to simulate the contact behavior between cradle and shell. For the inner shell, the actual 0.25" (6.3 mm) thickness is used with an extra weight to account for the weight of the inner shell fixture. The fixture is assumed to have no stiffness, which probably is on the conservative side. For the outer vacuum shell, a t^* and E^* is calculated based on the isogrid cell size (2). This equivalent thickness t^* and equivalent modulus E^* are used for the outer shell in the finite element analysis to give the correct structure stiffness. The stress are calculated by finite element program for both inner shell and bulkhead. They are very small (Table 1) compared with the allowable stress of 10 ksi (68 MPa) for aluminum. For the isogrid shell, the stress is not directly available from ANSYS, further data treatment is necessary. By extracting a resultant force (N_x, N_y, N_{xy}) and resultant moment (M_x, M_y, M_{xy}) for a given element, the membrane stress and bending stress were calculated by using the approach given in reference 2. The maximum skin stress is found to be about 370 psi (2.5MPa), which is also very small. The structure deflection is found to be less than 0.008" (0.2 mm), which is considered to be acceptable.

This calculation assumes the shell is supported by a cradle at each end. In fact, as-built structure (Fig. 2) has three 10 " cradles instead of two 12" cradles and slightly different cradle structure. The cradle structure assumed for this calculation results in higher stress than will be present when actual cradle in used.

Table 1

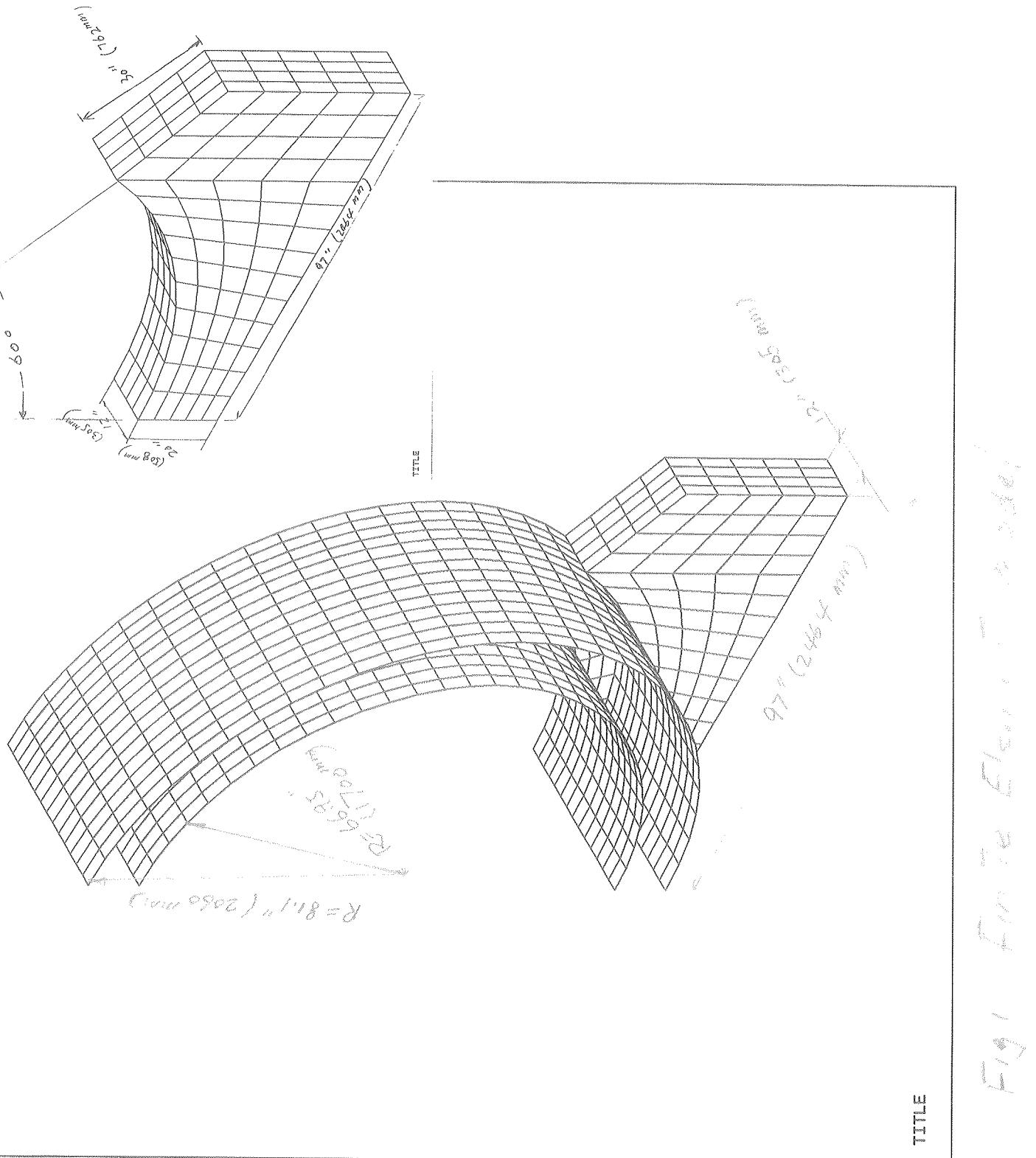
inner shell	bulkhead	outer shell	cradle(12"/305 mm)	deflection
944 psi (6.42 MPa)	322 psi (2.19 MPa)	370 psi (2.52 MPa)	254 psi (1.73 MPa)	< 0.008" (<0.2 mm)

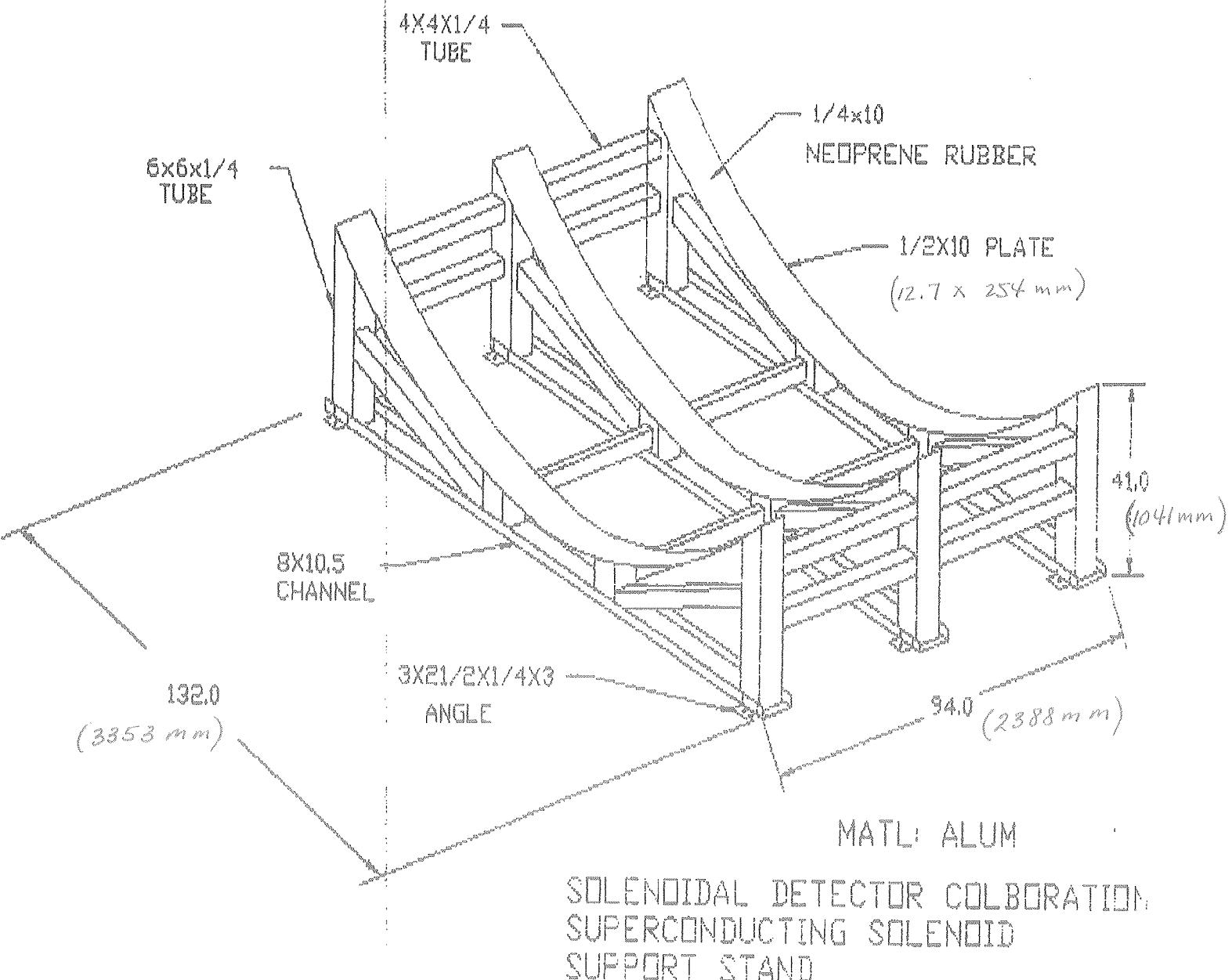
REFERENCES:

1. L.P. Zick, " Stress in Large Horizontal Cylindrical Pressure Vessel on Two Saddle Supports", Reprinted from Welding Journal Research Supplement, 1951, pp556-566
- 2.L.W.Swenson,"Buckling and stress Analysis of the SDC (Isogrid) Vacuum Shell", SDC, DN-154, Aug. 30, 1991

Appendix

- A) Isogrid geometrical Parameter Calculation
- B) Isogrid stress calculation from reference 2
- C) Subrouting used to calculate B above
- D) Spread sheet provided by R. Fast





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Appendix A

Isogrid Geometrical Parameter Calculation.

Appendix A

Iso grid geometrical Parameters.

$$\left. \begin{array}{l} a = 7.092'' \\ b = 0.15'' \\ c = 0.31'' \\ d = 1.73'' \\ h = 6.1419'' \\ w = 1'' \\ t = 0.16'' \end{array} \right\} \quad \left. \begin{array}{l} a = \frac{b+d}{h+t} = 0.264 \\ \beta = 27.82749 \\ \gamma = \frac{c}{t} = 10.8125 \\ \pi = \frac{c}{t} = 1.9375 \\ \mu = \frac{w \cdot c}{h \cdot t} = 0.3135 \end{array} \right.$$

$$t^* = t \frac{\beta}{1 + \alpha + M} = 2.818''$$

$$F^* = F \frac{(1 + \alpha + M)}{\beta} = 9.235 \times 10^5 \text{ psi.}$$

$$A^* = t^* (1 + \alpha + M) = 0.16 (1 + 0.264) + 0.3135) \\ = 0.2527.$$

$$Z_{bar} = t + \frac{d}{2} + \frac{t (1 + d - 4(8 + \lambda))}{2(1 + \alpha + M)} = 0.6305$$

$$C_f = t + d + c - Z_{bar} = 0.16 + 1.73 + 0.31 \\ - 0.6305 = 1.5695$$

$$C_s = \frac{Z_{bar}}{b} = \frac{0.6305}{b}$$

$$I = \frac{t^3 \cdot \beta^2}{12} (1 + \alpha + \mu)$$

$$\frac{0.163 \times 27.82749^2}{12} (1 + 0.2641 + 0.3155)$$

$$= 0.4175$$

$$D = \frac{q}{8} EI = \frac{q}{8} \times 10.3 \times 10^6 \times 0.4175$$

$$= 44.83778 \times 10^6$$

$$K = \frac{q}{8} E A = \frac{q}{8} \times 10.3 \times 10^6 \times 0.2527$$

$$= 2.97816 \times 10^6$$

Appendix B

Isogrid stress calculation from "Reference 2"

Appendix B

$$\left\{ \begin{array}{l} F_x \\ F_y \\ M_{xy} \end{array} \right\} = \frac{1}{A} \left\{ \begin{array}{l} N_x \\ N_y \\ -N_{xy} \end{array} \right\} + \frac{C_s}{I} \left\{ \begin{array}{l} M_x \\ M_y \\ M_{xy} \end{array} \right\}$$

$$\left\{ \begin{array}{l} F_x \\ F_y \\ M_{xy} \end{array} \right\} = \frac{N_x}{A} + \frac{C_s M_x}{I}$$

$$\left\{ \begin{array}{l} F_y \\ M_{xy} \end{array} \right\} = \frac{N_y}{A} + \frac{C_s M_y}{I} \quad \Rightarrow \text{ slow.}$$

$$\left\{ \begin{array}{l} F_x \\ F_y \\ M_{xy} \end{array} \right\} = \frac{-N_{xy}}{A} + \frac{C_s M_{xy}}{I}$$

$$F_x = \frac{N_x}{A} - \frac{1}{3A} NY - \frac{C_s I}{I} \left(M_x - \frac{M_y}{3} \right)$$

$$F_y = \frac{1}{A} \left(\frac{2}{3} NY - \frac{2}{3} N_{xy} \right) - \frac{C_s I}{I} \left(\frac{2M_x}{3} + \frac{2}{3} M_{xy} \right)$$

$$M_{xy} = \frac{1}{A} \left(\frac{2}{3} NY + \frac{2}{3} N_{xy} \right) - \frac{C_s I}{I} \left(\frac{2}{3} M_y - \frac{2}{3} M_{xy} \right)$$

= FOR RIB.

The section parameters given above are computed as follows:

$$\begin{aligned}
 A &= t(1 + \alpha + \mu) \\
 Cf &= t + d + C - z_{\text{bar}} \\
 Cs &= -z_{\text{bar}} \\
 E^* &= E(1 + \alpha + \mu)^2/\beta \\
 I &= t^3 \beta^2/12(1 + \alpha + \mu) \\
 D &= 9/8 E I \\
 K &= 9/8 E A \\
 t_{\text{eff}} &= A \\
 t^* &= t \beta/(1 + \alpha + \mu) \\
 \bar{t}_{\text{bar}} &= t(1 + 3\alpha + 3\mu) \\
 z_{\text{bar}} &= t + d/2 - t[1 + \delta - \mu(\delta + \tau)]/2(1 + \alpha + \mu)
 \end{aligned} \tag{1}$$

From shell theory, the force and moment stress resultants are given by the following equations (note that for aluminum Isogrid, Poisson's ratio equals 1/3):

$$\begin{Bmatrix} N_x \\ N_y \\ N_{xy} \end{Bmatrix} = K \begin{bmatrix} 1 & 1/3 & 0 \\ 1/3 & 1 & 0 \\ 0 & 0 & -1/3 \end{bmatrix} \begin{Bmatrix} \epsilon_x^* \\ \epsilon_y^* \\ \gamma_{xy}^* \end{Bmatrix} \tag{2}$$

and

$$\begin{Bmatrix} M_x \\ M_y \\ M_{xy} \end{Bmatrix} = D \begin{bmatrix} 1 & 1/3 & 0 \\ 1/3 & 1 & 0 \\ 0 & 0 & 1/3 \end{bmatrix} \begin{Bmatrix} \gamma_x \\ \gamma_y \\ 2\gamma_{xy} \end{Bmatrix} \tag{3}$$

respectively. In these equations, ϵ^* and X are the centroidal axis strains and curvatures, respectively.

The shell strains at a distance z from the reference surface are given by:

$$\begin{Bmatrix} \epsilon_x \\ \epsilon_y \\ \gamma_{xy} \end{Bmatrix} = \begin{Bmatrix} \epsilon_x^* \\ \epsilon_y^* \\ \gamma_{xy}^* \end{Bmatrix} - \gamma \begin{Bmatrix} \gamma_x \\ \gamma_y \\ 2\gamma_{xy} \end{Bmatrix} \tag{4}$$

If equations (1) and (2) are inverted,

$$\begin{Bmatrix} \varepsilon_x^o \\ \varepsilon_y \\ \gamma_{xy} \end{Bmatrix} = \frac{9}{8K} \begin{bmatrix} 1 & -1/3 & 0 \\ -1/3 & 1 & 0 \\ 0 & 0 & 8/3 \end{bmatrix} \begin{Bmatrix} N_x \\ N_y \\ N_{xy} \end{Bmatrix} \quad (5)$$

and

$$\begin{Bmatrix} \gamma_x \\ \gamma_y \\ 2\gamma_{xy} \end{Bmatrix} = \frac{-9}{8D} \begin{bmatrix} 1 & -1/3 & 0 \\ -1/3 & 1 & 0 \\ 0 & 0 & 8/3 \end{bmatrix} \begin{Bmatrix} M_x \\ M_y \\ M_{xy} \end{Bmatrix} \quad (6)$$

and substituted into equation (3), the shell strains can be written as:

$$\begin{Bmatrix} \varepsilon_x \\ \varepsilon_y \\ \gamma_{xy} \end{Bmatrix} = \frac{9}{8K} \begin{bmatrix} 1 & -1/3 & 0 \\ -1/3 & 1 & 0 \\ 0 & 0 & 8/3 \end{bmatrix} \begin{Bmatrix} N_x \\ N_y \\ N_{xy} \end{Bmatrix} + \frac{93}{8D} \begin{bmatrix} 1 & -1/3 & 0 \\ -1/3 & 1 & 0 \\ 0 & 0 & 8/3 \end{bmatrix} \begin{Bmatrix} M_x \\ M_y \\ M_{xy} \end{Bmatrix} \quad (7)$$

or,

$$\begin{Bmatrix} \varepsilon_x \\ \varepsilon_y \\ \gamma_{xy} \end{Bmatrix} = \frac{1}{EA} \begin{bmatrix} 1 & -1/3 & 0 \\ -1/3 & 1 & 0 \\ 0 & 0 & 8/3 \end{bmatrix} \begin{Bmatrix} N_x \\ N_y \\ N_{xy} \end{Bmatrix} + \frac{3}{EI} \begin{bmatrix} 1 & -1/3 & 0 \\ -1/3 & 1 & 0 \\ 0 & 0 & 8/3 \end{bmatrix} \begin{Bmatrix} M_x \\ M_y \\ M_{xy} \end{Bmatrix} \quad (8)$$

Use of the definitions of A and I were made in equation (8).

Isogrid Skin Stresses

Isogrid skin stresses are computed using the constitutive relations for plane stress:

$$\begin{Bmatrix} \sigma_x \\ \sigma_y \\ \tau_{xy} \end{Bmatrix} = \frac{2E}{\delta} \begin{bmatrix} 1 & -1/3 & 0 \\ -1/3 & 1 & 0 \\ 0 & 0 & 1/3 \end{bmatrix} \begin{Bmatrix} \epsilon_x \\ \epsilon_y \\ \gamma_{xy} \end{Bmatrix} \quad (9)$$

If the shell strains in equation (8) are substituted into equation (9), and the extreme shell fiber $z = C_s$ is identified, then the skin stresses are given by:

$$\begin{Bmatrix} \sigma_x \\ \sigma_y \\ \tau_{xy} \end{Bmatrix} = \frac{1}{A} \begin{Bmatrix} N_x \\ N_y \\ -N_{xy} \end{Bmatrix} + \frac{C_s}{I} \begin{Bmatrix} M_x \\ M_y \\ M_{xy} \end{Bmatrix} \quad (10)$$

Isogrid Rib Stresses

Isogrid rib stresses can be computed for strains as follows [5]:

$$\begin{Bmatrix} \sigma_1 \\ \sigma_2 \\ \sigma_3 \end{Bmatrix} = \frac{E}{4} \begin{bmatrix} 4 & 0 & 0 \\ 1 & 3 & 1/\sqrt{3} \\ 1 & 3 & -1/\sqrt{3} \end{bmatrix} \begin{Bmatrix} \epsilon_x \\ \epsilon_y \\ \gamma_{xy} \end{Bmatrix} \quad (11)$$

If the shell strains in equation (8) are substituted into equation (11), and the extreme rib fiber $z = -C_f$ is identified, then the rib stresses are given by:

$$\begin{Bmatrix} \sigma_1 \\ \sigma_2 \\ \sigma_3 \end{Bmatrix} = \frac{1}{A} \begin{bmatrix} 1 & -1/3 & 0 \\ 0 & 2/3 & -2/\sqrt{3} \\ 0 & 2/3 & 2/\sqrt{3} \end{bmatrix} \begin{Bmatrix} N_x \\ N_y \\ N_{xy} \end{Bmatrix} - \frac{C_f}{I} \begin{bmatrix} 1 & -1/3 & 0 \\ 0 & 2/3 & 2/\sqrt{3} \\ 0 & 2/3 & -2/\sqrt{3} \end{bmatrix} \begin{Bmatrix} M_x \\ M_y \\ M_{xy} \end{Bmatrix} \quad (12)$$

Subscripts on the rib stresses are indicated in Figure A.2.

Appendix C.

Subroutine used to calculate stress.

Appendix C. Subroutine and Sample

```
nums=1
numf=420
*****
:lp1
*get,nnx,tx,nums
*get,nny,ty,nums
*get,nnxy,txy,nums
*get,mmx,mx,nums
*get,mmy,my,nums
*get,mmxy,mxy,nums
nnxy=-nnxy
mmxy=-mmxy
*****
d=4.83778e6
i=0.4175
k=2.92816e6
cf=1.5695
cs=0.6305
a=0.2527
*****
sx=(Nnx/a)+(cs*mmx/i)
sy=(nny/a)+(cs*mmy/i)
sxy=(-nnxy/a)+(cs*mmxy/i)
sss1=(sx+sy)/2
sss2=((sx-sy)/2)**2
sss2=(sss2+(sxy*sxy))**0.5
s1=sss1+sss2
s2=sss1-sss2
se=((s1*s1)+(s2*s2)-(2*0.333*s1*s2))**0.5
rib1=(nnx/a)-(nny/(3*a))-((cf/i)*(mmx-(mmy/3)))
rib2=((2*nny/3)-(1.155*nnxy))/a)-((cf/i)*((2*mmy/3)+(1.155*mmxy)))
rib3=((2*nny/3)+(1.155*nnxy))/a)-((cf/i)*((2*mmy/3)-(1.155*mmxy)))
*****
/out,14
elem=nums
sx=sx
sy=sy
sxy=sxy
s1=s1
s2=s2
se=se
rib1=rib1
rib2=rib2
rib3=rib3
*****
/out,6
nums=nums+1
*if,nums,le,numf,:lp1
```

PARAMETER= ELEM 1.000
PARAMETER= SX -1.875
PARAMETER= SY -177.0
PARAMETER= SXY -4.606
PARAMETER= S1 -1.754
PARAMETER= S2 -177.1
PARAMETER= SE 176.6
PARAMETER= RIB1 66.54
PARAMETER= RIB2 -120.7
PARAMETER= RIB3 -100.3

PARAMETER= ELEM 2.000
PARAMETER= SX 6.510
PARAMETER= SY -191.0
PARAMETER= SXY 0.3475E-01
PARAMETER= S1 6.510
PARAMETER= S2 -191.0
PARAMETER= SE 193.3
PARAMETER= RIB1 58.08
PARAMETER= RIB2 -131.1
PARAMETER= RIB3 -114.4

PARAMETER= ELEM 3.000
PARAMETER= SX 19.15
PARAMETER= SY -197.3
PARAMETER= SXY 1.126
PARAMETER= S1 19.15
PARAMETER= S2 -197.3
PARAMETER= SE 204.4

PARAMETER= RIB1 36.81
PARAMETER= RIB2 -145.8
PARAMETER= RIB3 -119.1

C*****

PARAMETER= ELEM 4.000
PARAMETER= SX 39.08
PARAMETER= SY -193.0
PARAMETER= SXY 0.7322
PARAMETER= S1 39.08
PARAMETER= S2 -193.0
PARAMETER= SE 209.3
PARAMETER= RIB1 -3.693
PARAMETER= RIB2 -152.1
PARAMETER= RIB3 -129.6

C*****

PARAMETER= ELEM 5.000
PARAMETER= SX -6.009
PARAMETER= SY -187.4
PARAMETER= SXY -9.007
PARAMETER= S1 -5.563
PARAMETER= S2 -187.9
PARAMETER= SE 186.1
PARAMETER= RIB1 73.77
PARAMETER= RIB2 -143.2
PARAMETER= RIB3 -121.3

C*****

PARAMETER= ELEM 6.000
PARAMETER= SX 2.811
PARAMETER= SY -185.3

PARAMETER= SXY 20.24
PARAMETER= S1 -4.913
PARAMETER= S2 -270.8
PARAMETER= SE 269.2
PARAMETER= RIB1 19.76
PARAMETER= RIB2 -161.4
PARAMETER= RIB3 -208.1

C*****

PARAMETER= ELEM 36.00
PARAMETER= SX 6.568
PARAMETER= SY -236.5
PARAMETER= SXY 21.44
PARAMETER= S1 8.444
PARAMETER= S2 -238.3
PARAMETER= SE 241.3
PARAMETER= RIB1 -39.03
PARAMETER= RIB2 -144.6
PARAMETER= RIB3 -221.6

C*****

PARAMETER= ELEM 37.00
PARAMETER= SX -25.03
PARAMETER= SY -360.5
PARAMETER= SXY 41.58
PARAMETER= S1 -19.96
PARAMETER= S2 -365.6
PARAMETER= SE 359.4
PARAMETER= RIB1 121.6
PARAMETER= RIB2 -276.7
PARAMETER= RIB3 -322.9

Appendix D :

Spread sheet provided by Ron Fast.

Table 2-1. Materials for Prototype Vacuum Vessel

Parameter	Outer shell	Inner shell	Inner shell flanges	Bulkheads	Ref.	Nozzle, nozzle flange, blind flange	Ref.
Alloy	5083-H321	5083-0	5083-H112	5083-H112		6061-T6 (all)	
Vendor	Alcoa	Ryerson	Ryerson	Ryerson	1	Fermilab	na
Supplier	Alcoa	Alcoa	Alcoa	Alcoa, Reynolds	2	na	
Young's modulus, Msi (GPa)	10.3 (71.0)	10.3 (71.0)	10.3 (71.0)	10.3 (71.0)	3	10.0 (68.95)	3
Poisson's ratio	0.33	0.33	0.33	0.33	na	0.33	na
Weight density lb/in^2 (kg/m^3)	0.096 (2657)	0.096 (2657)	0.096 (2657)	0.096 (2657)	4	0.098 (2713)	4
Min. tensile ultimate strength, ksi (MPa)	44.9 (309.6)	44.0 (303.4)	43.7 (301.3)	43.7 (301.3)	2	24.0 (165.5)	3
Min. tensile yield strength, ksi (MPa)	34.3 (236.5)	25.4 (175.1)	21.2 (146.2)	21.2 (146.2)	2	16.0 (110.3)	3
Allowable stress, ksi (MPa)	10.0 (69.0)	10.0 (69.0)	9.8 (76.6)	9.8 (76.6)	3	6.0 (41.4)	3
Note: All properties are at room temperature.							
References:							
1. Purchase Order							
2. Certified Inspection Report							
3. ASME Pressure Vessel Code, Section II, Part D (1992)							
4. Aluminum Standards and Data, Aluminum Association of America (1990)							

2/20/2023

Table 2-2. Geometry of Prototype Vacuum Vessel

a. Outer (isogrid) vacuum shell

Fermilab drawing number	SSC-SDD-000376
Outer shell material	5083-H321
Outer shell outer diameter	162.2 in (4120 mm)
Outer shell length	92.126 in (2340 mm)
Estimated weight	2100 lb (955 kg)

525 lb.

b. Inner vacuum shell

Fermilab drawing number	SSC-SDD-000381
Inner shell material	5083-0
Inner shell inner diameter	133.9 in (3400 mm)
Inner shell length	92.126 in (2340 mm)
Inner shell thickness	0.25 in (6.3 mm)
Estimated weight, including flanges	1250 lb (568kg)

312.5 lb

c. Bulkheads

Fermilab drawing number	SSC-SDD-000382
Bulkhead material	5083-H112
Bulkhead outer radius	81.102 in (2060 mm)
Bulkhead inner radius	66.929 in (1700 mm)
Thickness	1.22 in (31 mm)
Estimated weight for two, w/o holes	1600 lb (727 kg)

600 lb

d. Chimney nozzle assembly

Fermilab drawing number	SSC-SDD-000372
Nozzle pipe material	6061-T6
Nozzle flange material	6061-T6
Blind flange material	6061-T6
Nozzle pipe outer diameter	12.75 in (323.8 mm)
Nozzle pipe wall thickness	0.180 in (4.6 mm)
Nozzle flange thickness	0.875 in (22.2 mm)
Blind flange thickness	0.75 in (19.0 mm)
Weight of assembly	25 lb (11.4 kg)

e. Inner vessel fixture

Amro drawing number	
Estimated weight	1000 lb (455 kg)

280 lb

f. Total weight rounded up to nearest 100 lb

Estimated weight of vessel	5000 lb (2273 kg)
Weight of vessel with fixture	6000 lb (2727 kg)
Internal (cold) mass	13200 lb (6000 kg)

= 8.7

$$V_{\text{model}} = 4787.5 \text{ lbf}$$

Table 2-3. Isogrid Geometry

a. Regular pattern

Fermilab drawing number		SSC-SDD-000365
Node spacing	a	7.092 in (180.1 mm)
Web width	b	0.150 in (3.81 mm)
Flange depth	c	0.310 in (7.87 mm)
Web depth	d	1.730 in (43.94 mm)
Triangle height	$h=a\sqrt{3}/2$	6.1419 in (156.0 mm)
Flange width	w	1.000 in (25.4 mm)
Skin thickness	t	0.160 in (4.06 mm)

b. Nozzle reinforcement pattern

Fermilab drawing number	SSC-SDD000413 Sh 2 of 4
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c. Panel joint pattern

Fermilab drawing numbers	SSC-SDD-000365, -000375
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Table 2-4 Isogrid Dimensionless Parameters

To be determined by PSA.

Table 2-5 Isogrid Section Parameters

To be determined by PSA.

2.3 Applied Loading

Task 1

There are three static forces to be considered when analyzing the vacuum vessel. The primary force is a vacuum loading of 15 psi, which is an external pressure on the outer shell, an internal pressure on the inner shell, and an axial pressure toward the symmetry plane on the bulkheads. The second force is the mass (weight) of the vessel. A third force is the cold mass of the superconducting coil inside the annular vacuum space. The vacuum vessel will be shipped by truck and ship from Amro Fabricating Corporation to the Toshiba plant in Yokohama, Japan. The completed magnet will be shipped by truck from the Toshiba plant to the KEK laboratory.

The vacuum vessel alone

The completed magnet could be operated with the axis either horizontal or vertical. There are, therefore, three ways in which the cold mass might be applied to the bulkheads during operation. These are given in Table 2-6.

The completed magnet will be shipped from Toshiba to KEK with the axis vertical in one of two orientations. We have assumed a 3-g shipping load in all three directions. The three ways the cold mass might be applied to the bulkhead during shipping are given in Table 2-7.

Table 2-6 Force on Bulkheads from Cold Mass during Operation

A. With Axis Horizontal, Force on Each Bulkhead

Point of application in	r mm	ϕ degrees*	Direction*	Force at Point of Application (actual weight)	
				lbf	kgf
74.055	1881	82.25	-y (90°)	3300	1500
74.055	1881	277.75	-y (90°)	3300	1500

B. With Axis Vertical, Force on Chimney End Bulkhead Only

Point of application in	r mm	ϕ degrees*	Direction**	Force at Point of Application (actual weight)	
				lbf	kgf
75.827	1926	10.0	$\pm z$	943	429
75.827	1926	35.0	$\pm z$	943	429
75.827	1926	62.5	$\pm z$	943	429
75.827	1926	90.0	$\pm z$	943	429
75.827	1926	117.5	$\pm z$	943	429
75.827	1926	145.0	$\pm z$	943	429
75.827	1926	170.0	$\pm z$	943	429
75.827	1926	190.0	$\pm z$	943	429
75.827	1926	215.0	$\pm z$	943	429
75.827	1926	242.5	$\pm z$	943	429
75.827	1926	270.0	$\pm z$	943	429
75.827	1926	297.5	$\pm z$	943	429
75.827	1926	325.0	$\pm z$	943	429
75.827	1926	350.0	$\pm z$	943	429

Table 2-7 Force on Bulkheads from Cold Mass during Shipping from Toshiba to KEK

A. With Axis Horizontal, Force on Each Bulkhead

Point of application			Direction*	Force at Point of Application (3 x actual weight)	
	r in	mm	ø degrees*	lbf	kgf
74.055	1881		82.25	-y (90°)	9900
74.055	1881		277.75	-y (90°)	9900

B. With Axis Vertical, Force on Chimney End Bulkhead Only

Point of application			Direction**	Force at Point of Application (3 x actual weight)	
	r in	mm	ø degrees*	lbf	kgf
75.827	1926		10.0	±z	2829
75.827	1926		35.0	±z	2829
75.827	1926		62.5	±z	2829
75.827	1926		90.0	±z	2829
75.827	1926		117.5	±z	2829
75.827	1926		145.0	±z	2829
75.827	1926		170.0	±z	2829
75.827	1926		190.0	±z	2829
75.827	1926		215.0	±z	2829
75.827	1926		242.5	±z	2829
75.827	1926		270.0	±z	2829
75.827	1926		297.5	±z	2829
75.827	1926		325.0	±z	2829
75.827	1926		350.0	±z	2829

* Zero degrees is indicated in drawing SSC-SDD-000382.

** +z direction is outward from the chimney-end bulkhead

The vessel and the completed magnet will rest on the floor (or truck bed) in three possible orientations, as shown in Fig 2-1. The load paths to the floor are listed in Table 2-8.

Table 2-8 Load Paths to Floor

A. Horizontal Orientation

Load	Load path
Vacuum	Not required
Inner shell weight	Inner shell to bulkheads to outer shell to cradle to floor
Bulkhead weight	Bulkhead to outer shell to cradle to floor
Outer shell weight	Outer shell to cradle to floor
Cold mass	Bulkheads to outer shell to cradle to floor

B. +z Vertical Orientation

Vacuum	Not required
Inner shell weight	Inner shell to floor
Chimney-end bulkhead	To floor
Other-end bulkhead	Bulkhead to inner and outer shells to floor
Outer shell weight	Outer shell to floor
Cold mass	To floor

C. -z Vertical Orientation

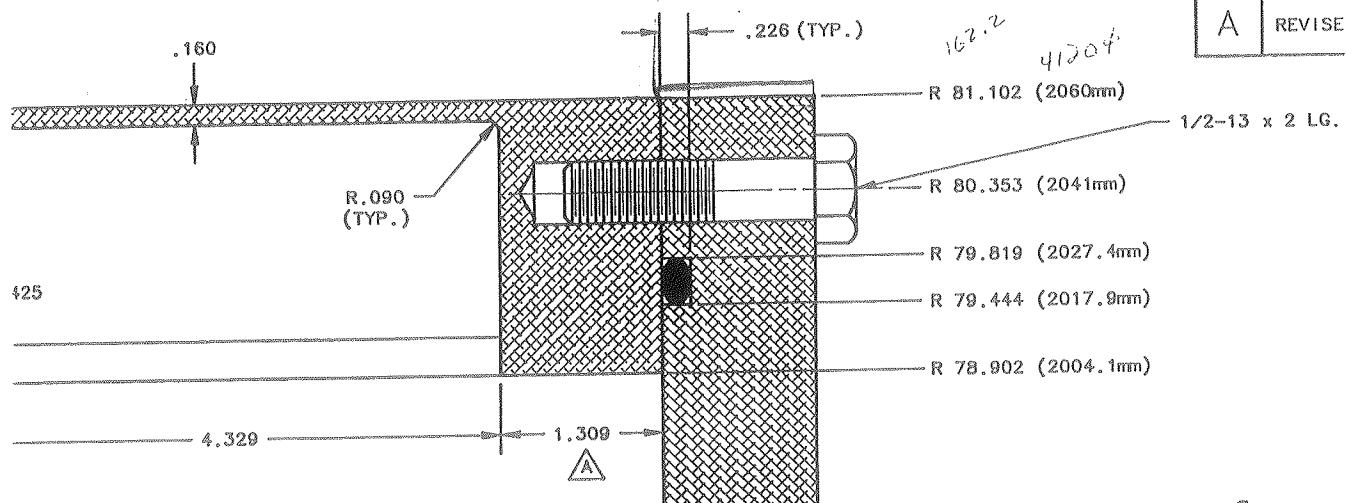
Vacuum	Not required
Inner shell weight	Inner shell to floor
Chimney-end bulkhead	Bulkhead to inner and outer shells to floor
Other-end bulkhead	To floor
Outer shell weight	Outer shell to floor
Cold mass	Chimney-end bulkhead to shells to floor

The vacuum vessel is to be analyzed by PSA for the operating and shipping load cases given in Table 2-7.

Table 2-8 Load-Orientation Cases to be Studied

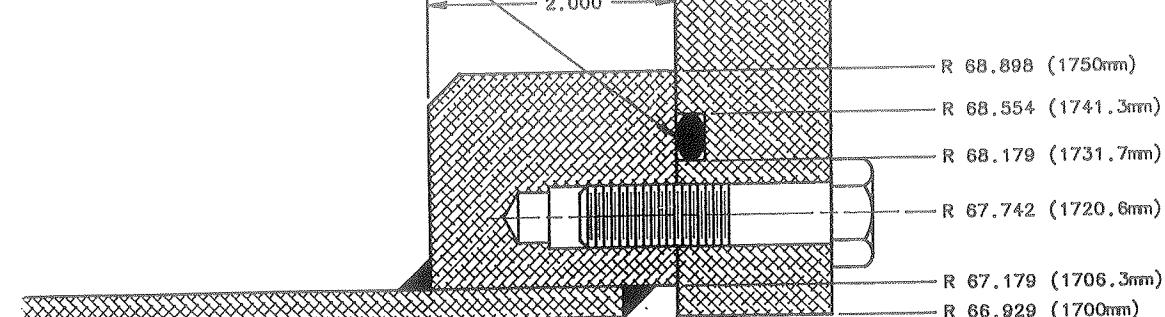
Load case	Operating Cases		Orientation +z Vert.	-z Vert.
	Horiz.			
Vacuum only	x			
Vacuum plus weight of vessel and fixture	x		x	
Vacuum plus weight of vessel and fixture and cold mass	x		x	x
Shipping Cases--No Vacuum				
Three times weight of vessel and fixture	x		x	
Three times weight of vessel and fixture and three times cold mass	x		x	x

REV.	
A	REVISE



1/4 NOMINAL DIA. O-RING
(.275 DIA. CROSS-SECTION)
(TYP.)

2.000



ITEM NO.	PART

UNLESS OTHERWISE

FRACTIONS DECIM

± ±

1. BREAK ALL S 1/64 MAX.
2. DO NOT SCALE
3. DIMENSION WITH ANSI Y

MAX. A
SL



SOLEI

PROTO

SCALE	DR
FULL	

NOTES

1. MAKE FROM JIS A3E3 OR CORRESPONDENT MATERIAL.
2. REMOVE ALL EYES AND BREAK SHARP EDGES.
3. CLEAN TO REMOVE GREASE, OIL AND OTHER CONTAMINANTS.
4. TO TAKE CARE THAT KEEP O RING SEAL SURFACES TO BE FREE FROM ANY DAMAGE, SCRATCH AND SO ON.

